



US006474159B1

(12) **United States Patent**  
**Foxlin et al.**

(10) **Patent No.:** **US 6,474,159 B1**  
(45) **Date of Patent:** **Nov. 5, 2002**

(54) **MOTION-TRACKING**

(75) Inventors: **Eric Foxlin**, Arlington, MA (US); **Yury Altshuler**, Chestnut Hill, MA (US)

(73) Assignee: **Intersense, Inc.**, Burlington, MA (US)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/556,135**

(22) Filed: **Apr. 21, 2000**

(51) **Int. Cl.**<sup>7</sup> ..... **G01P 15/00**

(52) **U.S. Cl.** ..... **73/488**

(58) **Field of Search** ..... 73/488, 503.3,  
73/504.03, 570, 514.01; 600/587, 595;  
128/897, 898, 774, 782; 367/117, 118;  
33/333, 355 R

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

5,645,077 A \* 7/1997 Foxlin ..... 128/774  
6,176,837 B1 \* 1/2001 Foxlin ..... 600/595

**OTHER PUBLICATIONS**

E. Foxlin, "Head-tracking relative to a moving vehicle or simulator platform using differential inertial sensors", 2000.  
E. Fuchs, "Inertial head-tracking", M.S. Thesis, Dept. of E.E.C.S., MIT, 1993.  
E. Foxlin, "Inertial head-tracker sensor fusion by a complementary separate-bias kalman filter", Proc. VRAIS '96 Virtual Reality Annual Intl. Symposium, Santa Clara, CA 1996.  
E. Foxlin et al., "Miniature 6-DOF inertial system for tracking HMDs", SPIE vol. 3362, Proc. AeroSense '98 Conference on Helmet- and Head-Mounted Displays III, Orlando, FL 1998.

InterSense Inc. homepage—<http://www.isense.com>.

K. Britting, "Inertial navigations systems analysis", New York, Wiley Interscience, 1971.

C. Broxmeyer, "Inertial navigation systems", New York, McGraw-Hill, 1964.

R. Parvin, "Inertial Navigation", Princeton, New Jersey, Van Nostrand, 1962.

R.G. Brown et al., "Introduction to random signals and applied Kalman filtering", 2<sup>nd</sup> edition, New York, John Wiley & Sons, 1992.

\* cited by examiner

*Primary Examiner*—Helen Kwok

(74) *Attorney, Agent, or Firm*—Fish & Richardson P.C.

(57) **ABSTRACT**

Inertial trackers have been successfully applied to a wide range of head mounted display (HMD) applications including virtual environment training, VR gaming and even fixed-base vehicle simulation, in which they have gained widespread acceptance due to their superior resolution and low latency. Until now, inertial trackers have not been used in applications which require tracking motion relative to a moving platform, such as motion-base simulators, virtual environment trainers deployed on board ships, and live vehicular applications including helmet-mounted cueing systems and enhanced vision or situational awareness displays. to the invention enables the use of inertial head-tracking systems on-board moving platforms by computing the motion of a "tracking" Inertial Measurement Unit (IMU) mounted on the HMD relative to a "reference" IMU rigidly attached to the moving platform.

**42 Claims, 7 Drawing Sheets**

